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Institute for Manufacturing and Sustainment Technologies

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QUARTERLY 2005 No.1

In-situ Submarine Vertical Launch System Repair Update

iMAST's Repair Technology Program (RepTech) continues to address a portion of the "sustainment" effort within the Institute for Manufacturing and Sustainment Technologies. RepTech strives to produce out-of-the-box repair solutions which will enhance readiness throughout the fleet, and depot community—at an affordable cost. RepTech's "change the repair paradigm" philosophy is accomplished by injecting innovative ARL Penn State "perspectives" that can invigorate aging field repair practices and techniques.

Keying on this philosophy, ARL's Eric Whitney is executing an *in-situ* project effort relative to submarine Vertical Launch System (VLS) missile tubes. Whitney and his ARL Laser Processing Division colleagues, in cooperation with project team members at the Naval Undersea Warfare Center Division Keyport's Rapid Prototyping Division, and Pearl Harbor Naval Shipyard and IMA (PHNSY & IMA) have designed and developed a modular, man-portable, in-situ grinding/laser cladding tool for VLS missile tube repairs. This is a comprehensive self-deployable pier-side repair system that will save an estimated 128 man-hours per missile tube versus the arduous hand-held brush electroplating and grinding process that is currently employed.

One challenging hard-line requirement set forth by the PHNSY & IMA, relative to VLS repair innovation, is system portability that will eliminate the use of service cranes. To address this issue, the project team designed modular kits that accommodate easy crane-free assembly and breakdown. To maximize productivity, the team designed the system for one time set-up, to include pre-grinding, laser cladding, and finish stoning.

Once this system and process is approved by the Naval Sea Systems Command technical authority (SEA 05), the complete system will be delivered to PHNSY & IMA for integration with their FY06 industrial laser purchase in Shop 38's waterfront machinists facility. PHNSY & IMA plans to repair all VLS missile tubes (approximately 300) in the Pacific Fleet within 3 years.

For more information on iMAST's Repair Technology Program, contact Sean Krieger at (814) 863-0896, or e-mail at <slk22@psu.edu>. For questions about laser cladding, contact Eric Whitney at (814) 865-3916, or e-mail at <ejw111@psu.edu>.

Focus On Laser Processing Technologies

Report Documentation Page

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DIRECTOR'S CORNER

Full Swing

Hello. The new year is in full swing and projects are proceeding toward their goals. A number of projects supporting the DDX are nearing completion and others supporting the next generation carrier have commenced. A number of technologies are showing strong promise toward reducing the acquisition costs for future ships. As you may be

aware, there is a lot of pressure for reducing the costs of building ships. The high cost of the very capable platforms is limiting the ability of the Navy to fund the number of ships necessary to maintain the fleet at current levels. Another item to consider in the ship design is the need to reduce the manning, as manning drives a large portion of total ownership costs. At the same time, it is desirable to maintain capability at as high a level as possible. All of these challenges are part of ongoing projects.

This newsletter features laser fabricated stiffened structures. This technology holds the promise of weight reduction in applications aboard carriers. ARL successfully built similar sections which were installed on the USS *Mount Whitney* (LCC 20) in 1994.

The next focus area for the Navy's Manufacturing Technology is the Littoral Combat Ship (LCS). The Navy is aggressively pursuing the acquisition of the new ship type, funding the manufacture of competing designs in a relatively short timeframe. There are probably many opportunities to improve manufacturing processes associated with this new design ship, as it will possibly include many non-traditional concepts and materials.

What does the Institute for Manufacturing and Sustainment Technologies offer? Not only do we have the talent and experience of knowledgeable and dedicated engineers and scientists, we have innovative and enthusiastic students, plus the resources of The Pennsylvania State University, which has one of the best materials research capabilities in the world. Take advantage of us!

Bob Cook

MATERIALS PROCESSING TECHNOLOGIES

MECHANICAL DRIVE TRANSMISSION TECHNOLOGIES

LASER PROCESSING TECHNOLOGIES

COMPLEX SYSTEMS MONITORING TECHNOLOGIES

ADVANCED COMPOSITES MATERIALS TECHNOLOGIES

NAVY/MARINE CORPS REPAIR TECHNOLOGIES

MANUFACTURING SYSTEMS TECHNOLOGIES

Focus on Laser Processing Technologies

Laser Welded Lightweight Structures

by Kenneth C. Meinert, Jr.

Lightweight structures for naval vessels are receiving considerable interest because of the potential to reduce the overall weight of a ship, thus allowing for improvements in capability, such as increased load capacity or reduced power requirements for propulsion. Since many other shipboard systems are being improved with time, so are the methods and materials used to fabricate the ship itself. The Laser Processing Division of the Applied Research Laboratory (ARL-Penn State) has been addressing affordable laser fabricated lightweight structures for some time. One particular structure that ARL-Penn State has been developing is LASCOR, an acronym for LASer welded lightweight CORrugated structure.

LASCOR can be likened to a common packaging material – corrugated cardboard, a lightweight, strong, and stiff material for its simple construction. LASCOR is analogous to this structure, consisting of two sheets of metal that are joined to a corrugated metal core by laser welding, as shown in Figure 1. Laser welding is the joining process of choice due to its low heat input, which minimizes the thermal distortion and high production speeds, and its ability to produce the lap weld.

LASCOR offers great flexibility in the design, as the core geometry and material thickness can be modified to meet the needs of the application, and it can be fabricated from a variety of weldable metals, such as stainless and high-strength steel, aluminum, and titanium. LASCOR samples, representing different materials and configurations are shown in Figure 2.

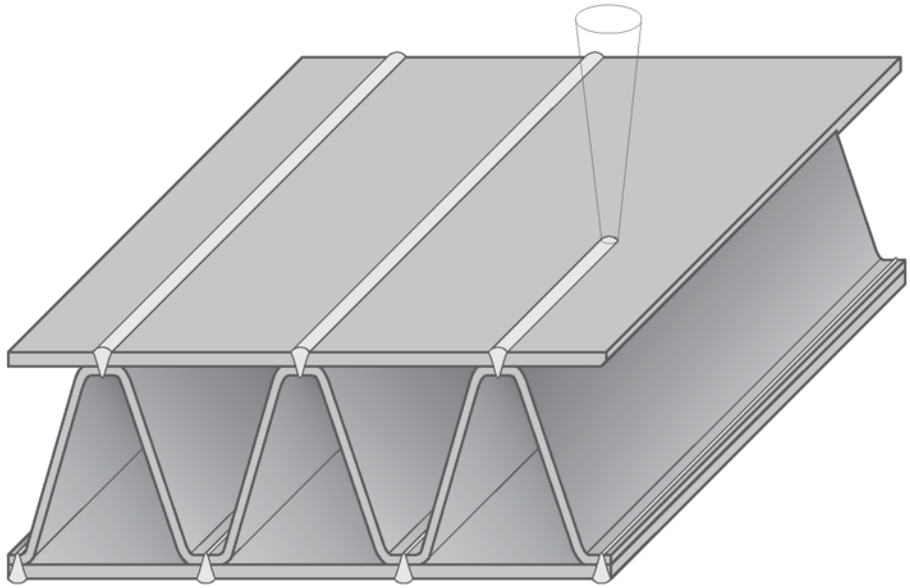

Figure 1. Schematic of a LASCOR panel showing a laser beam being used to join the cover sheet to the core.

This material offers the primary benefit of reducing the ship topside structural weight (i.e. physical characteristic) which improves overall ship stability (i.e. performance) and KG margin. LASCOR is a relatively thin structure, typically 2-inches thick, while a comparable beam stiffened plate is 4 to 6 inches in height, as shown in Figure 3. Thus the use of LASCOR, instead of conventional structure, can potentially increase or improve usable deck height due to the inherent self-stiffness of the panels.

An additional secondary benefit is reduced outfitting. Piping is routed to all areas of the ship, and the various T-stiffeners that fill the compartments require that the piping be routed around or through them. The flat surfaces offered by LASCOR simplify the outfitting as detailed in Figure 4. It is also possible that the spaces between the cover sheets can be used as cableways or for narrow piping applications.

LASCOR has been used in limited applications for the U.S. Navy; including antenna platforms for the LCC-

PROFILE

Ken Meinert has been employed at the Applied Research Laboratory for the past ten years in the Laser Processing Division. His work has included development of laser welding, cutting, cladding, and surface treatment processes for a wide variety of defense-related items, including torpedo components, aircraft carrier trough covers, missile casings, tank heat exchangers, ordnance, and naval propellers. He has experience with a wide variety of materials, including aluminum, copper, nickel, and iron alloys as well as metal matrix composites.

Mr. Meinert received his B.S and M.S. degrees in Engineering Science and Mechanics from the Pennsylvania State University. He is currently pursuing a Ph.D. in metallurgy. He can be reached at (814) 863-7281 or by e-mail at: <kcm104@psu.edu>.

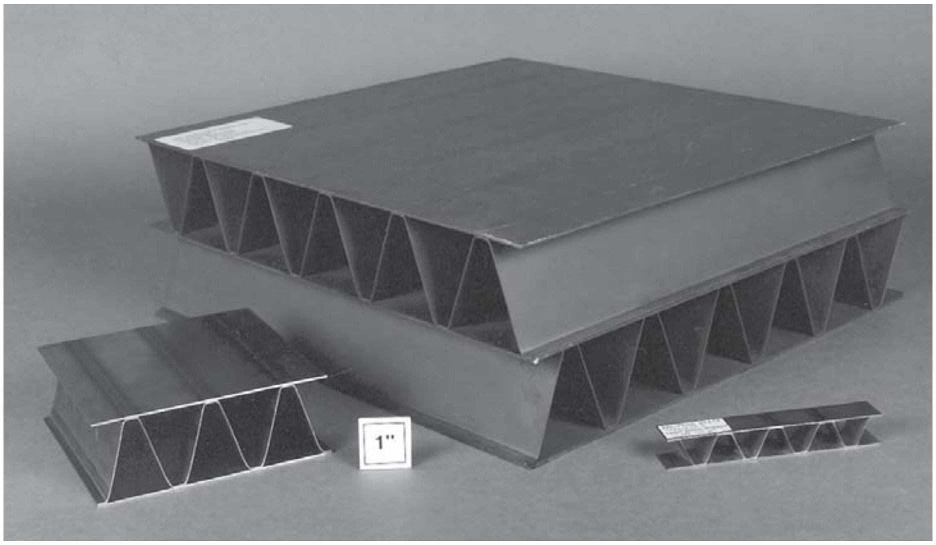

Figure 2. LASCOR samples, various configuration and materials

20, the U.S.S. *Mt. Whitney*. The panels for these two platforms were fabricated at the Applied Research Laboratory in 1993, fabricated into the antenna platforms and installed aboard ship at Newport News in February 1994. The installed platforms are shown (arrow) on the U.S. Navy photo in Figure 5. The installation aboard the U.S.S. *Mt. Whitney* involved two platforms, one port, and one starboard. The two platforms were composed of 2,100 square feet of stainless steel alloy 316L LASCOR, which resulted in a weight savings of 20,000 lbs. (approximately 40%), compared to traditional beam stiffened plate designs. These platforms are still in use, and owing to its inherent strength of LASCOR, additional equipment has been recently installed on them.

Although several different applications for LASCOR have been developed, each fabrication run was performed on a case-by-case basis. Only minor attention was paid to its manufacturability and cost. Unfortunately, the issues related to fabrication are not trivial, and plans for increased usage require that the manufacturing process used to fabricate the material be fully developed for a production environment to ensure low-cost manufacturing of these structures for U.S. Navy applications.

In order to make these structures more available for naval ship construction, a Navy ManTech program has been initiated to evaluate the manufacturing aspects of LASCOR. This includes investigating low-cost methods for fabrication of the corrugated material, developing improved fixture design methods, and generating workcell requirements for commercial manufacture. The focus of the current ARL Penn State effort is to enable production of LASCOR-type structures in a cost-effective manner.

Fabrication Issues

Although laser welding is used to fabricate the structures, laser welding is not the primary difficulty in production. Laser beam welding has been shown to be ideally suited for fabrication of these structures; however, the most difficult LASCOR production issues are the fabrication of the core material and the fixturing of the separate pieces for welding.

Laser welding is a very precise process, requiring tight tolerances and good contact between the core and cover sections during the welding operation. The laser welds are blind—made from the top cover sheet into the core, which requires that the landing of the core be accurately maintained so that the welds can be properly placed. Therefore, the core material must be fabricated to maintain proper core spacing and linearity along the length, as well as proper core height. Maintaining core dimensions is key to the fabrication

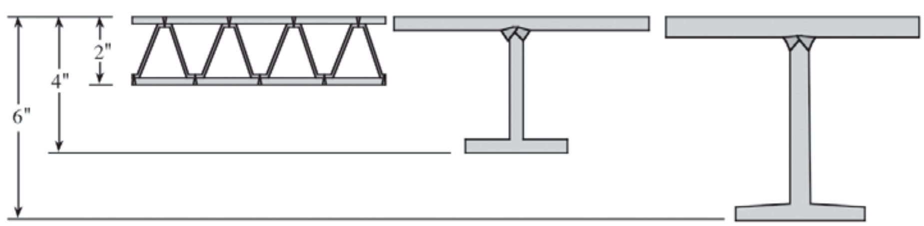

Figure 3. Height comparison of LASCOR vs. conventional beam stiffened plate. This comparison is representative only and does not reflect equivalent mechanical performance.

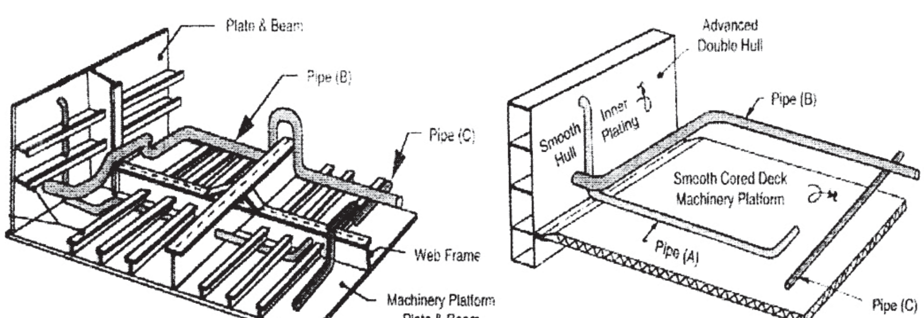

Figure 4. Outfitting differences between beam stiffened plate and LASCOR. Courtesy of Naval Surface Warfare Center-Carderock.

Figure 5. Antenna Platforms on the U.S.S *Mt. Whitney* (arrowed).

of quality panels. Several forming methods are currently being evaluated including press brake and roll forming. These methods have the ability to produce the quality core material required for the panels. But each have both advantages and disadvantages that must be considered, with determinations made as to which method will be most appropriate in a particular application.

Once a satisfactory core material forming process is identified, emphasis will be placed on the fixture design to ensure good contact between the cover sheets and the core material. The variability of the forming process, the laser beam welding process, and the fixturing method will all impact contact requirements. Without good contact between the face sheet and the core, there is likelihood of an undercut weld, or (if a sufficient gap exists) the laser beam will simply melt through the top sheet without bonding to the core. These conditions are unacceptable and will require rework of the panel, adding to fabrication time.

In the past, all of the cover sheets and core were tacked prior to final welding, this operation joined the three sections with no noticeable distortion. During subsequent welding operations to fully weld the joints, the tacks allowed the assembly to distort while maintaining contact. Although an effective solution, this method doubled the time required to produce a panel, since the panel was welded twice, once for the tack welds, and a second time for the continuous welds. Eliminating the tack welding operation will clearly increase productivity.

A fixture design has been developed at ARL Penn State to eliminate tacking, while maintaining contact between the core and cover sheets during the welding process. The fixture (shown in Figure 6) is based on a clamshell design, wherein a rigid fixture holds the three components of the panel in place. The rigidity of the fixture is designed such that it will hold any weld distortion in check, holding the panel in the flat condition during welding. This will eliminate the need for the tacking step previously described.

When welding on one side of the panel is completed the fixture rotates (Figure 7) with welding taking place on the reverse side.

The panels for the LCC-19 were fabricated from 1/4 hard 316L stainless steel. Although that material has good properties, other type of stainless steels, duplex stainless steels are available. Duplex stainless steels have higher strength, greater ductility, and better corrosion resistance in seawater environments. The higher strength allows for a reduction in the weight of the LASCOR, while the improvement in corrosion will allow this structure to remain intact for many years.

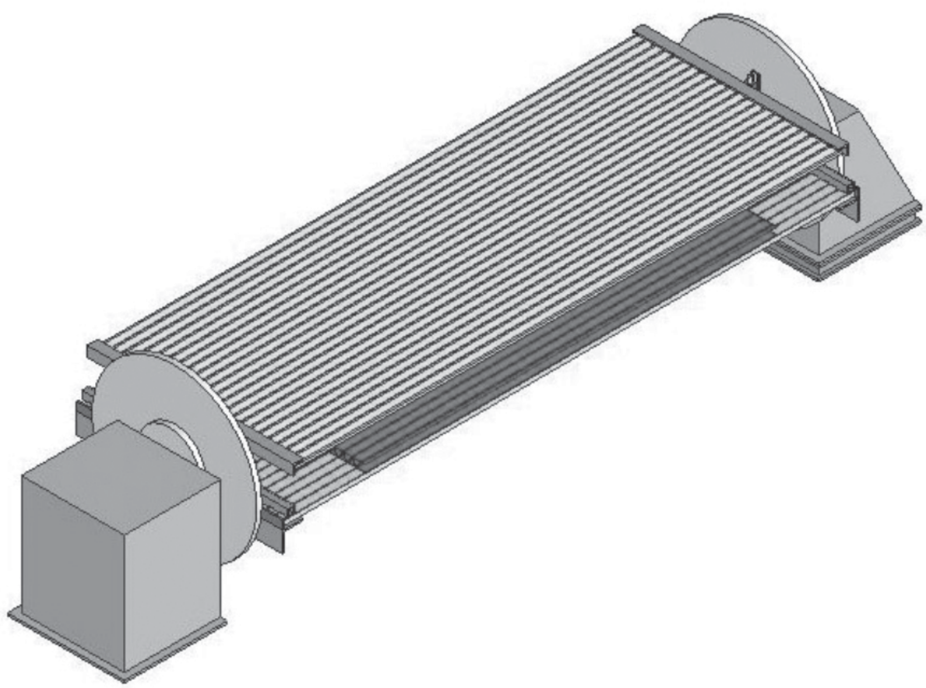

Figure 6. Computer rendering of the fixture design.

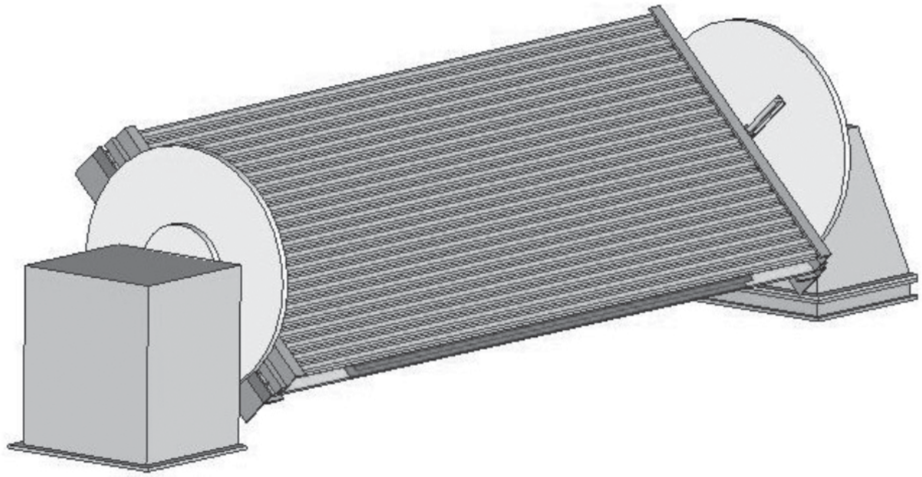

Figure 7. Computer rendering of the fixture design, showing rotation to weld the opposite side of the panel.

The use of the duplex stainless steels requires the development of new laser welding procedures. To improve the fabrication rate, there is a desire to weld as fast as possible; however, the nature of duplex stainless steels requires that weld have an appropriate composition of phases to maintain its strength and corrosion resistance. There is therefore a need to perform a series of weld evaluations to determine the appropriate laser processing parameters that meet the needs of production while maintain the mechanical and corrosion properties of these materials.

Those processing parameters are currently being evaluated, initially through metallurgical analysis of samples representing a matrix of laser welding parameters. Test samples will then be prepared and analyzed to determine the optimal processing window for the duplex stainless steel alloys.

Cost Model

A model has been developed to determine the effects of the various aspects of manufacture on the final cost of the fabricated panel. Initially, the model determines the mechanical properties of the panel based on overall dimensions of the thickness, sheet material, and the geometry of the core. Once the panel has been defined, the model uses the overall panel size and core geometry to determine the material required and estimates the cost of core fabrication, using either roll forming or press braking. For the laser processing aspect of production, the model estimates the time required to weld the panel based on the thickness of the material, panel dimensions, core geometry, and the characteristics of the laser. It also identifies costs related to fixturing, as well as labor costs that occur when the panel is not being welded. Finally, it calculates an estimated cost for shipment of the panels, based on the dimensions and weight of the panel and the selected shipping method. All costs are then tallied to determine the total cost of the panel.

Meeting Future Challenges

Development of DDX, CVN21 and Littoral Combat Ships (LCS) demands the introduction of innovative maritime shipbuilding technologies. ARL Penn State is addressing various applications, such as LASCOR, that will provide affordable, lightweight structures to support the maintainance of a viable naval force. Changing threats are altering the way our leaders are evaluating our domestic security. New forms of asymmetric warfare will demand increased vigilance at sea. Our new ships must be able to shoulder the challenges facing them by incorporating the necessary technologies that give us the edge—at an affordable cost. Program goals include the development of processes and procedures that will enable affordable production of LASCOR material in the U.S. This includes all aspects of production, including the core manufacture specification, fixture design requirements, laser welding development and qualification procedures, and fabrication of panels for analysis and testing. When the program is complete, panels will be available for use in the construction of U.S. Navy vessels. We believe LASCOR is a viable solution.

When the program is complete, the methodology for panel fabrication will be defined, a qualification plan will be in place for implementation to meet U.S. Navy requirements. At least one domestic commercial supplier will be available for production to fabricate the material for the U.S. Navy.

Acknowledgement

The author wishes to express appreciation for support of this effort by the Institute for Manufacturing and Sustainment Technologies (iMAST), a U.S. Navy Center of Excellence sponsored under contract by the Navy Manufacturing Technology Program, Office of Naval Research. Any opinions, findings, conclusions and recommendations expressed in this material are those of the author and do not necessarily reflect the views of the U.S. Navy.

RepTech Working Group Meets

Members of the Repair Technology Working Group recently met at ARL Penn State to review current and future project efforts. The working group was created to develop a coordinated approach to identify RepTech needs for the Navy and the Marine Corps. The group is represented by members of the various Navy and Marine Corps systems commands and the Marine Corps Maintenance Directorate. RepTech applies appropriate technologies to improve capabilities of the remanufacture and repair community. It plays a central role in using emerging technologies to improve the repair process and the affordability of Navy and Marine Corps repair facilities. Repair Technology investments are necessary to close gaps between the capability of the repair process and the sustainment needs of various weapon systems. For more information about this program, contact Sean Krieger at (814) 863-0896 or by e-mail at <slk22@psu.edu>.

Secretary England chats with ARL staff.

Surface Navy Association Symposium 2005

Members of iMAST recently participated in the annual Surface Navy Association Symposium held in Crystal City, Virginia. Addressing the theme “Sea Basing”, ARL’s iMAST program provided numerous examples of manufacturing technology expertise that can support one of the principle pillars of Seapower 21, Sea Basing. In addition to numerous uniform leaders of the Navy visiting ARL’s booth, Secretary of the Navy Gordon England stopped by iMAST’s exhibit booth to view ARL’s full-scale ATT mock-up and listen to Dr. Tom Donnellan explain a host of materials and manufacturing capabilities. iMAST expects to attend and participate in this event again next year (January 2006). For more information about the Surface Navy Association, visit their website at: <http://www.navysna.org/default.asp>.

NAVY MANTECH
manufacturing technology program

iMAST Participates in ShipTech 2005

Members of the Applied Research Lab at Penn State recently attended the annual ShipTech 2005 forum in Biloxi, Mississippi. ShipTech is a two-day event intended as a forum for the domestic shipbuilding industry, its supplier base, the U.S. Navy Program Offices and the U.S. Navy-sponsored shipbuilding research programs to exchange information on shipbuilding technical developments. ShipTech provides a forum to highlight advances generated respectively by the National Shipbuilding Research Program and the Navy ManTech Program through its Centers of Excellence and related shipbuilding initiatives. The overriding objective of the information exchange is to reduce total ownership costs of naval ships while enhancing the competitiveness of the domestic shipbuilding industry. For information about next year’s forum, refer to future iMAST newsletters.

John Fraschilla, Marc Angelucci, Tim Ehret, and Mike Koch of Lockheed Martin pause for a photo with ARL’s Tom Donnellan, associate director for materials and manufacturing.

Lockheed Martin Visit

Members of Lockheed Martin’s Electronics Business, Maritime Systems & Sensors division (of Moorestown, New Jersey) recently visited ARL Penn State as part of a capabilities assessment review. The Maritime Systems & Sensors (MS2) provides surface, air, and undersea applications on more than 460 programs for U.S. military and international customers. ARL addressed numerous issues to include lightweight materials, digital RF developments, thermal management materials and techniques, RF components, MMICs and packaging, data/signal distribution, thermoacoustic developments, and power conditioning distribution. The meeting concluded with a visit to ARL’s synthetic environments applications laboratory.

CALENDAR OF EVENTS

19–21 Apr.	NDIA Science and Engineering Technology Conference DoD Tech Exposition		Charleston, SC
2–4 May	Navy Opportunity Forum		Reston, VA
2–5 May	U.S. Coast Guard Innovation Expo		Santa Clara, CA
10–11 May	ARL Materials and Manufacturing Advisory Board (Aerospace focus)		State College, PA
16–17 May	Penn State Flight Simulation and Avionics Course		State College, PA
1–3 Jun.	American Helicopter Society Forum 61	★★★★★★★ *visit the iMAST booth*	Grapevine, TX
2–3 Jun.	Johnstown Showcase for Commerce	★★★★★★★ *visit the iMAST booth*	Johnstown, PA
21 Jun.	Mega Rust 2005 (Offshore Marine Coatings and Corrosion Conference)		Louisville, KY
11–14 Jul.	National SBIR Phase II Conference: Ready for Transition		San Diego, CA
26–28 Jul.	ONR Naval-Industry R&D Partnership Conference	★★★★★★★ *visit the iMAST booth*	Washington, D.C.
Aug. TBA	TechTrends 2005	★★★★★★★ *visit the ARL booth*	TBA
Aug. TBA	ARMTech 2005	★★★★★★★ *visit the iMAST booth*	Kittanning, PA
15–19 Aug.	Penn State Rotary Wing Short Course		State College, PA
17–19 Aug.	ARMTech	★★★★★★★ *visit the iMAST booth*	Kittanning, PA
Sep. TBA	Combat Vehicle Conference		Ft. Knox, NY
13–15 Sep.	Marine Corps League Expo	★★★★★★★ *visit the iMAST booth*	Quantico, VA
Oct. TBA	Expeditionary Warfare Conference		Panama City, FL
Oct. TBA	DoD Maintenance Conference		TBA
Oct. TBA	AUSA Expo		Washington, D.C.
16–19 Oct.	AGMA Gear Expo 2005		Detroit, MI
24–27 Oct.	NDIA Expeditionary Warfare Conference		Panama City, FL
Nov. 28–1 Dec.	Defense Manufacturing Conference	★★★★★★★ *visit the iMAST booth*	Orlando, FL

Quotable

"To be prepared for war is one of the most effective means of preserving peace."

—George Washington

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